Identification of Sustainable Supply Chain Performance in Primary Cocoa Processing (Case Study in Patuk, Yogyakarta)

Tasyarafa Shelia Khairani[1], Muhammad Prasetya Kurniawan[1], Kuncoro Harto Widodo[1], Tri Marwati[2], Titiek Farianti Djaafar[2]

[1]Department of Agro-industrial Technology, Faculty of Agricultural Technology, Universitas Gadjah Mada, Indonesia 55281, tasyarafashelia@mail.ugm.ac.id (T.S.K); kurniawan_prasetya@ugm.ac.id (M.P.K); kuncorohw@ugm.ac.id (K.H.W)
[2]National Research and Innovation Agency, Indonesia 55281, trim011@brin.go.id (T.M); titi033@brin.go.id (T.F.J)

Corresponding author: Muhammad Prasetya Kurniawan (kurniawan_prasetya@ugm.ac.id)

Abstract

This study identified the handling of dry fermented cocoa bean production, analyzed the level of cocoa supply chain (SC) performance in Patuk, and developed recommendations for poor performance to improve SC performance. In this study, environmentally friendly handling was carried out by observing the SC and processing process, and SC performance was measured based on the Supply Chain Operations Reference (SCOR) model in the scope of reliability, responsiveness, and agility supported by the 2.2 Analytical Hierarchy Process (AHP) weighting method using pairwise comparison. The result of this study indicates that sustainable practices from the seeding, nurturing, harvesting, and shipping stages are easier to implement due to the small scale and proximity to residential areas and processing units. Cocoa SC performance in Patuk is divided into 3 parts, namely for farmer performance (79.79), collective traders (70.23), and processing industry (83.29). Improvements that can be made to improve the performance of the SC are by increasing plant maintenance, recording production, and making contracts. The benefits of this study are to encourage the adoption of environmentally friendly cocoa cultivation and processing practices, provide information on SC factors on SC performance, and provide recommendations for performance improvement.

Key words: *Analytical hierarchy process*, *Cocoa*, *Performance*, *Processing*, Supply chain operations reference

1. Introduction

The aspect of environmental sustainability involves the wise management of natural resources. In cocoa farming, the use of water, soil, and energy must be carefully managed so as not to over-drain these resources or damage natural ecosystems. Sustainable farming practices should support biodiversity, including protecting plants, insects, and microorganisms that contribute to the balance of agricultural ecosystems. This biodiversity can help control natural pests and increase agricultural productivity, which in turn affects the income of supply chain actors, especially farmers [1]. In cocoa bean processing, waste management and processing must be done properly. The selection of environmentally friendly methods to dispose of waste and the use of renewable energy can reduce negative impacts on the environment. This proper management can contribute greatly to sustainable development [2].

Cocoa is one of the plantation commodities in Indonesia that plays an important in the development of agro-industry [3]. One of the regions in Indonesia that has many cocoa plantations is the Special Region of Yogyakarta. 13.77% of cocoa plantations in Yogyakarta are located in Gunungkidul Regency [4], covering an area of 1,373.5 ha with an average production of 0.75 tonnes/ha and the plantations in Gunung Kidul involve 8,752 heads of farming families [5]. One of the sub-districts in Gunungkidul that has the most cocoa land area is Patuk Sub-district with a cocoa land area of 710 ha.

Cocoa supply chain activities in Patuk Sub-district involve several levels ranging from farmers, collective traders, and processing industries. Farmers ini this supply chain are the cocoa plantation owners. They carry out activities to plant and cultivate cocoa land and produce wet cocoa beans as their end products. The collective trader's role in this supply chain is to process the wet cocoa beans delivered by the farmers into dry cocoa beans which will be handed over to the processing industries. Processing industries play a role in producing various processed cocoa products as final products such as pure cocoa powder which can be used to produce various types of processed cocoa products.

Cocoa fruit has a harvesting period of about 4-5 months which causes production at each level to adjust to the availability of cocoa fruit. Based on preliminary observations in the field, cocoa beans ordered by collective traders often do not match the demand where collective traders request wet cocoa beans in the amount of 25 kg, but the order of wet cocoa beans coming

from farmers is only 21.8 kg. This shows that sometimes the number of orders coming is below the demand. Some cocoa farmers in the Patuk Subdistrict also do not routinely deposit wet cocoa beans to collective traders following the routine schedule, so sometimes the number of cocoa fruit suppliers is different every month. The inconsistent procurement of raw materials causes production to have no fixed schedule and fluctuating production results to fulfill the demands of processing industries that have certain specifications for the cocoa beans ordered.

Based on the description of the cocoa supply chain condition in Patuk Sub-district, several things need to be analyzed related to the supply chain activities of each supply chain actor because each activity affects the other. This study aims to analyze the level of performance of the cocoa supply chain in the Patuk Sub-district and develop development recommendations for poor performance. Performance metrics in the SCOR model are used as indicators of supply chain performance measurement because it uses a vertical approach and the weighting of performance indicators is determined using AHP to determine the level of importance of performance indicators. In this study, SCOR and AHP can be used together or separately in the cultivation and processing of fresh cocoa pods into fermented dry beans at the farm level to ensure that these practices support environmental sustainability in the long term.

2. Methods

2.1 SCOR Model

Key Performance Indicators (KPIs) are determined based on business processes at farmers, collective traders, and processing industries using the SCOR Model. The SCOR model is based on 6 main processes, namely Plan, Source, Make, Deliver, Return, and Enable [6]. This research focuses on customers so it only uses 3 performance attributes, namely reliability, responsiveness, and agility.

2.2 Analytical Hierarchy Process

Determination of the level of importance of processes, performance attributes, and KPIs in this study was carried out using weighting with the Analytical Hierarchy Process (AHP) method to determine which KPIs had poor performance so that recommendations for improvement could be given.

The weighting is carried out on the core process of SCOR which consists of 6 processes, namely plan, source, make, deliver, return and enable. The weighting is also carried out on SCOR performance attributes which focus on customer aspects, namely reliability, responsiveness and agility. These consumer focused attributes are used in this research since the research focuses on the performance of the process. weighting is also carried out on KPIs identified from SCOR performance metrics based on existing business processes at each tier to determine the performance of each KPI.

Data for weighting was obtained based on the results of a questionnaire using pairwise comparisons filled out by 23 respondents consisting of 17 farmers, 4 collective traders, and 2 processing industries. The data from the questionnaire was processed using Microsoft Excel to weigh the processes, performance attributes, and KPIs for each tier.

2.3 Snorm de Boer

The final performance value is calculated by multiplying the AHP weighting results by the normalization results, namely using Snorm de Boer which functions to equalize the matrix values used as indicators measured using the SCOR model [7]. In Snorm de boer normalization, the normalization categories used are higher is better and lower is better [8]. The following is the normalization formula for the categories of each indicator, namely:

1. Higher is better

$$Snorm = \frac{Si - Smin}{Smax - Smin} x\ 100 \quad (1)$$

2. Lower is better

$$Snorm = \frac{Smax - Si}{Smax - Smin} x\ 100 \quad (2)$$

3. Results and Discussions

Cocoa supply chain actors in the Patuk Sub-district consist of farmers, collective traders, and processors. Figure 1 shows the cocoa supply chain in the Patuk Sub-district. Cocoa cultivation in Nglanggeran is a transition from the initial activity of processing cassava into cassava chips. The traditional cocoa supply chain starts with farmers planting cocoa beans, tending them, and finally harvesting the beans. During the maintenance period, farmers often use pesticides and herbicides to eradicate common cocoa diseases such as cocoa pod borer (CPD) and vascular disease (VSD). The characteristics of cocoa farmers can be divided into three, namely owner farmers, tenant farmers, and field

extension workers from the local agricultural office. The harvest can be processed directly by farmers or purchased by processing units and supplied to local and regional companies. The fermentation and shelling process can improve the quality of dried cocoa beans, so these additional activities can increase the income of farmers, collectors, and processing units.

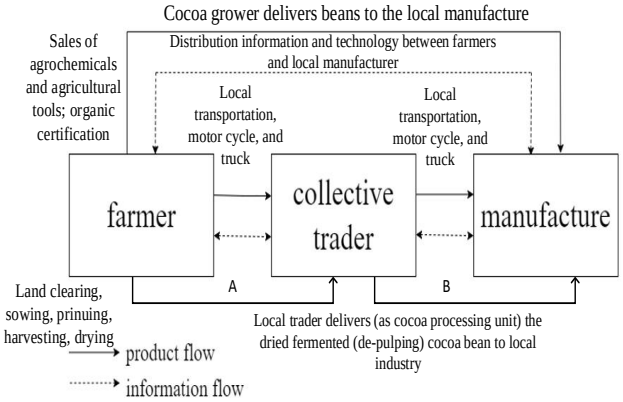

Fig 1. Local supply chain cocoa in the Patuk area

In each tier, farmers, collective traders, and processors consist of plan, source, make, deliver, return, and enable processes. KPIs were identified based on the business processes carried out by each tier which were then validated by all supply chain actors using an assessment questionnaire. KPI validation was processed using Aiken's V validation. The KPI validation results show that there are 15 KPIs from the reliability, responsiveness, and agility performance attributes that will be measured in the research. Figure 2 shows the AHP hierarchy model for this research.

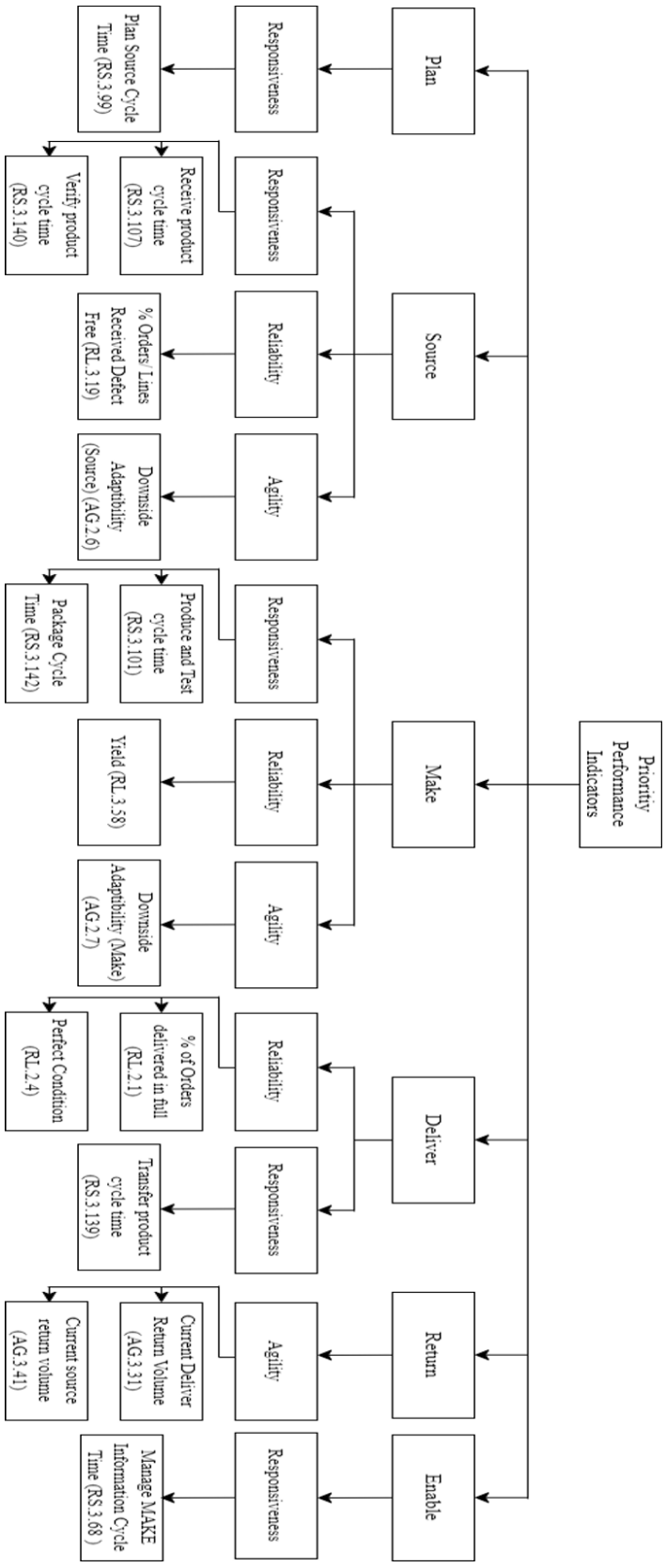

Fig 2. AHP Hierarchy

The final performance value is obtained using Snorm de Boer normalization multiplied by the AHP weighting results. Figure 3 is a table of performance calculation results for farmers and logistics scenarios for collective traders, and Figure 5 is a table of performance calculation results for the processing industry.

Table 1. Performance of Farmers

KPI	Weight	Snorm
Plan Source Cycle Time (RS.3.99)	0.09	92.61
Receive product cycle time (RS.3.107)	0.1	100
Verify product cycle time (RS.3.140)	0.04	100
% Orders/ Lines Received Defect Free (RL.3.19)	0.17	95.77
Downside Adaptability (Source) (AG.2.6)	0.05	84.33
Produce and Test cycle time (RS.3.101)	0.09	68.57
Package Cycle Time (RS.3.142)	0.03	75
Yield (RL.3.58)	0.18	44.94
Downside Adaptability (Make) (AG.2.7)	0.08	72.51
% of Orders delivered in full (RL.2.1)	0.03	84.69
Perfect Condition (RL.2.4)	0.02	66.46
Transfer product cycle time (RS.3.139)	0.03	75
Current Delivery Return Volume (AG.3.31)	0.02	100
Current source return volume (AG.3.41)	0.01	100
Manage MAKE Information Cycle Time (RS.3.68)	0.06	92.61

Table 2. Performance of Collective Traders

KPI	Weight	Snorm
Plan Source Cycle Time (RS.3.99)	0.06	73.33
Receive product cycle time (RS.3.107)	0.03	81.25
Verify product cycle time (RS.3.140)	0.01	83.33
% Orders/ Lines Received Defect Free (RL.3.19)	0.2	58.45
Downside Adaptability (Source) (AG.2.6)	0.08	52.63
Produce and Test cycle time (RS.3.101)	0.13	80
Package Cycle Time (RS.3.142)	0.02	100
Yield (RL.3.58)	0.18	69.71
Downside Adaptability (Make) (AG.2.7)	0.09	50
% of Orders delivered in full (RL.2.1)	0.01	73.91
Perfect Condition (RL.2.4)	0.08	67.39
Transfer product cycle time (RS.3.139)	0.05	70
Current Delivery Return Volume (AG.3.31)	0.02	100
Current source return volume (AG.3.41)	0.01	100
Manage MAKE Information Cycle Time (RS.3.68)	0.04	73.33

Table 3. Performance of Processing Industries

KPI	Weight	Snorm
Plan Source Cycle Time (RS.3.99)	0.1	64
Receive product cycle time (RS.3.107)	0.03	50

Verify product cycle time (RS.3.140)	0.01	76.68
% Orders/ Lines Received Defect Free (RL.3.19)	0.19	92.59
Downside Adaptability (Source) (AG.2.6)	0.08	76.92
Produce and Test cycle time (RS.3.101)	0.09	100
Package Cycle Time (RS.3.142)	0.03	62.5
Yield (RL.3.58)	0.27	85.19
Downside Adaptability (Make) (AG.2.7)	0.05	68.75
% of Orders delivered in full (RL.2.1)	0.01	100
Perfect Condition (RL.2.4)	0.01	80
Transfer product cycle time (RS.3.139)	0.01	65.63
Current Delivery Return Volume (AG.3.31)	0.02	100
Current source return volume (AG.3.41)	0.02	100
Manage MAKE Information Cycle Time (RS.3.68)	0.08	74

Based on the results of the supply chain performance calculation for each tier, it is known that the performance levels of farmers, collective traders, and processors based on the performance indicator monitoring system are good (79.79), average (70.23), good (83.29), respectively. In each tier, the KPI that has the lowest value for farmers is yield, for collective traders is downside adaptability (make), and the processing industries is receive product cycle time.

The problem in the farmer tier is poor yield performance so that several proposals are needed to improve their yield performance. Farmers need to design SOPs that discuss the sorting process of wet cocoa beans and the implementation of crop maintenance. Farmers also need to improve crop maintenance to avoid fruit rot disease attacking plants. Improving plant care can be done by creating a more planned schedule so that plant care can be carried out regularly and by increasing the intensity of wrapping cocoa pods in plastic to avoid disease. Apart from that, the local government also needs to conduct training related to cocoa plant care so that farmers can understand and implement the knowledge gained.

At the collective trader tier, the performance of concern is downside adaptability (make). The proposed improvement strategy that can be given for this problem is that the local government needs to hold training related to maintenance for collectors because one of the causes of this problem is limited and damaged equipment. The training aimed to give insights to this tier so that there is SOP can be designed regarding equipment maintenance and used as a guidance for them. Collective traders also need to conduct regular meetings on a more scheduled basis to avoid miscommunication between them and the farmers because some farmers did not deliver the materials at the specified time and quantity. They can also pick up materials directly from farmers to avoid miscommunication so that the production process can be carried out immediately without having to wait for late materials. Erratic seasons are also a problem at the collector tier, the proposed strategy is for the local government to provide assistance in the form of additional drying equipment so that the dried cocoa beans are not exposed to rain even though the drying process is not maximized and requires a longer time.

The lowest performance in the processing industry tier is receive product cycle time. The proposed improvement strategy that can be given for this problem is that the industry should pick up dry cocoa beans directly to collective traders without having to wait for them to send materials if the stock of dry cocoa beans has run out. This action is given based on the reason that the delivery from collective traders depend on a certain amount of products, while if the production of collective tarders is decreasing, it will extend the time for receiving materials by the industry. In addition, this direct pick-up of materials is also because some collective traders are also constrained by transportation that is not available to make deliveries. Miscommunication also often occurs between the processing industry and collective traders due to the absence of contracts related to delivery schedules and delivery conditions so it is necessary to have a contract that regulates these matters so that the process of delivering and receiving materials from suppliers to the processing industry can be more scheduled and clear. In addition, the processing industry also needs to record material stocks to avoid material shortages due to increased waiting time for materials to arrive from suppliers. By recording material stock, the processing industry can estimate the time of the next order to the supplier.

There are potential challenges in implementing the proposed improvements. The main implementation challenge is the government's limited access to provide training to all farmers and collective traders because they are located in different locations and not all tier parties feel that the training is urgent to improve the performance of their activities.

The source cycle time plan of farmers and collective traders enables monitoring and measurement of supply chain performance in terms of received product cycle time, adaptability, and product transfer, each of which contributes to the environmental impact of inputs and outputs. Monitoring of resource use efficiency, estimation of waste, and estimation of emissions, should be disseminated to farmers according to their adaptability. Furthermore, AHP is for the selection of nutrients and pesticides at the cultivation stage. Such monitoring can lead to sustainable cocoa farming [9] Processing techniques (drying and fermentation), energy use for transport, and waste utilization can be used to assess environmental risks. Farmers need to improve their ability to assess high environmental risks and take steps to minimize their impact in the future because one of the pillars of a sustainable cocoa supply chain is economic sustainability [9] and the stability of cocoa bean prices is one of the factors that need to be improved as an effort to improve sustainability in the cocoa supply chain in terms of socioeconomics [10].

4 Conclusion

Cocoa supply chain performance in Patuk Sub-district is divided into 3 parts, namely for farmer performance of 79.79, collective trader performance of 70.23, and processing industry performance of 83.29. Capacity building related to environmentally friendly handling and improvement recommendations given to improve farmer performance is to increase plant care, for collective traders is to make contracts with farmers and record production, for processing industries is to make contracts related to delivery schedules.

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